and acetylene to the torch. This can be accomplished by pressure regulators at the tanks and/or adjustment of the valves on the torch.

A preferred region for the welding rod in a torch flame having 3:1 ratio of cone lengths is between about one and two cm from inner flame cone tip; however it is difficult to maintain the tube rod in this small range during manual welding. Hence, this is a less preferred method of hard facing. The longer than usual flame with a 4:1 ratio provides a much longer zone within which the welding rod may be placed for achieving a low eta phase and oxide concentration in the matrix of the hardfacing.

The eta phase and oxide content in the matrix may be determined by polishing a cross-section of a tooth with hardfacing with incrementally decreasing sizes of diamond particles from 40 μm to 3 μm. The polished surface is then etched with a reagent of 10 g $KFe(CN)_6$, 10 g KOH and 100 ml water followed by an alcohol rinse. The eta phase and oxide content may be determined using a PGI Imagist image analyzer at 100× magnification.

The proportion of carbide in the hardfacing is determined largely by the proportion in the welding "rod" used for applying the hardfacing. Some dilution may occur by alloy steel from the surface of the tooth on the cutter cone. This dilution is not a large contributor since in a typical application of hardfacing to a milled tooth cutter cone for a rock bit, the thickness of hardfacing is in the order 2 mm. The amount of dilution depends to some extent on the technique employed by the welder applying the hardfacing.

The carbide content in the hardfacing can be estimated by metallographic examination of a cross section through the hardfacing. The approximate areas of the carbide and binder phases can be determined. From this, the volume percentages of binder and carbide can be estimated, and in turn the weight percentages. Since use of deoxidizer in the filler of a welding tube is important for producing void free binder phase, the dilution of the carbide filler can be taken into account and the ratio of filler weight to tube weight approximated. A hypothetical tube type welding rod can be projected from a hardfacing deposited on the surface by other techniques.

Thus, for consistency in this specification, the proportion of carbide to alloy steel in the hardfacing is considered on the basis of carbide content in the stick used to melt the hardfacing onto the surface. As pointed out above, the filler of carbide, binder and deoxidizer is 50% to 80% by weight (plus or minus 2%) of the stick and the mild steel tube is 20% to 50% by weight (plus or minus 2%). The filler is about 96% carbide (plus or minus 2%), with a balance of deoxidizer and binder.

The improved hardfacing material is applied to the gage surfaces of the cone and gage row teeth in the same manner previously described for applying the hardfacing mixture to the inner row teeth.

Abrasion tests show that the improved hardfacing materials of this invention exhibit improved wear and fracture resistance over hardfacing materials containing similar proportions of carbide particles but which do not include spherical cast carbide particles. For example, in a hardfacing comprising a carbide component with 70 percent by weight of 16 to 30 mesh crushed cemented carbide and 30 percent by weight of 40 to 80 mesh macrocrystalline carbide, it has been found that by substituting 40 percent by weight of the crushed cemented carbide particles with spherical cast carbide particles in the same size range, loss of hardfacing material due to sliding abrasion wear, chipping, and carbide particle fracture were significantly reduced. It is hypothesized that this improved performance is due to the advantages of both the material and geometry of the spherical cast tungsten carbide particles over the crushed cemented tungsten carbide particles they replace. Cast carbide is inherently harder than cemented carbide and hence is more resistant to abrasion wear. Also, it is believed that the spherical particles are less likely to fracture during actual field use than the crushed particles because although cast tungsten carbide is not inherently tougher than cemented tungsten carbide, the spherical particles lack the sharp edges of the crushed particles which act as stress concentrators and hence are more prone to fracture and breakage.

The improvement in performance of the hardfacing translates directly into increased footage of well drilled and increased rate of penetration, both of which translate directly into lowered costs for the driller.

Other modifications and variations of hardfacing for a rock bit will be apparent to one skilled in the art. It is, therefore, to be understood that within the scope of the appended claims, this invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A rock bit comprising:

a body;

at least one cutting cone rotatably mounted to an end of the body, wherein the cone includes a gage surface at a heel portion of the cone;

a number of teeth on the cone, the teeth including a plurality of inner row teeth and a plurality of gage row teeth located near a heel of each cone, wherein the teeth include a hardfacing comprising:

steel in the range of from 20 to 50 percent by weight; and

filler in the range of from 50 to 80 percent by weight, the filler comprising in the range of from 10 to 100 percent by weight spherical cast tungsten carbide particles having a particle size between about 16 to 40 mesh.

2. The rock bit of claim 1 comprising filler in the range of from 60 to 75 percent by weight.

3. The rock bit of claim 1 wherein the filler comprises in the range of from 20 to 50 percent by weight spherical cast tungsten carbide particles.

4. The rock bit of claim 1 wherein the filler comprises in the range of from 40 to 100 percent by weight spherical cast tungsten carbide particles.

5. The rock bit of claim 1 wherein the filler comprises in the range of from 10 to 99 percent by weight spherical cast tungsten carbide particles having a particle size between about 16 to 40 mesh, and further comprises tungsten carbide particles selected from the group consisting of spherical cemented, crushed cemented, crushed cast, crushed macrocrystalline, and carburized.

6. The rock bit of claim **5** wherein the filler further comprises spherical cast tungsten carbide particles having a particle size between about 80 to 200 mesh.

7. The rock bit of claim **6** wherein the filler comprises spherical cast tungsten carbide particles having a particle size between about 100 to 200 mesh.

8. The rock bit of claim **5** wherein the filler further comprises macrocrystalline tungsten carbide particles having a particle size between about 40 to 80 mesh.

9. A rock bit as recited in claim 1 wherein the hardfacing comprises in the range of from 10 to 90 percent by weight spherical cast tungsten carbide particles having a particle size between about 16 to 40 mesh, and further comprises ultra-fine tungsten carbide particles in the range of from 10